
Brief Communication

AMBULATORY EFFECTS OF BRIEF EXPOSURES TO MAGNETIC FIELDS CHANGING ORTHOGONALLY IN SPACE OVER TIME

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In a within-subject design adult male rats were exposed for 15 min once per day or night to one of two patterns of complex magnetic fields (0.5 to 1 micro T) rotated in space once every 2 s or 20 s through each of the three spatial dimensions and then simultaneously through all three dimensions. Open field behavior was then measured for ambulation, defecation, and grooming. The rats displayed about twice the ambulation after when the fields had been present compared to when they had not. The burst-firing field elicited the greatest ambulation when presented during the night whereas the frequency-modulated pattern elicited the greatest ambulation when presented during the day. These results suggest that robust behavioral changes can occur when rats are exposed for 15 min to complex spatiotemporal configurations of weak magnetic fields.

Keywords open field behavior, rat, rotating magnetic fields

There must be electromagnetic equivalents to all chemical reactions within the living system. It is assumed that application geometry of the magnetic field to simulate these effects must be complex temporally and spatially in order

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to approximate the conditions that define the interactions between receptors and ligands. This report describes the authors' first experiment with different application geometries of complex magnetic fields upon ambulatory behavior in the rat.

Open field (ambulatory) behavior was selected as the dependent variable because it is a wide-spectrum indicator of many classes of behavior. The three measures were ambulation, defecation, and episodes of grooming. Because the goal is to devise a technology that totally simulates the effects of specific drug actions, it was reasoned that any effect worthy of pursuit should be evident with a small sample size.

Consequently a total of 4 Wistar male rats, 150 days of age, were exposed on alternative days and nights to sham conditions or to magnetic field conditions for 15 min before testing for 2 min in the open field (Persinger, 1969). Testing during the day occurred during the mid-photophase (noon to 14 h) while testing during the night occurred in red light during the mid-scotophase (00 to 02 h).

The temporal structures of the fields were determined by a series of numbers between 0 and 255, which are converted by computer software to voltage (± 5 V). The first field generated a burst-pattern whereas the second field generated a frequency modulated pattern (Martin et al., 2004). The point duration of each number of the sequences for each of the 2 fields was 3 ms. The time between each presentation (0.5 s for each burst and 1 s for each frequency modulated field) was 4 s. Both fields were generated by an XT computer.

These magnetic fields were generated sequentially through pairs of solenoids that were oriented in each of the three spatial dimensions (McKay et al., 2000) with field intensities between 0.5 and 1 microT. These six solenoids were attached in the center of each of the six walls of the chamber. One cycle consisted of successive activations of the solenoids along the X axis, Y axis, Z axis and then finally all three axes simultaneously.

This sequence was designed because it was assumed, metaphorically, that the successive application of the field to each spatial dimension would displace the cellular reactions into the other two spatial dimensions but that the fourth stimulation of all three axes simultaneously would induce changes in a subtle temporal component. Because the authors did not have a theoretical prediction for how long the field must be presented, the commutator was selected to activate the fields for either 0.5 s or 5 s within each dimension.

All 4 rats were tested 16 times to the burst-firing or frequency-modulated pattern, fast rotation (0.5 s per solenoid pair, 2 s for spatial cycle) or slow rotation (5 s per pair of solenoids, 20 s for spatial cycle), no-field or field condition, or day or night testing. For any given day half the numbers of rats

were exposed to the field while the other two were placed in the chamber with the equipment operating (but input disconnected).

The numbers of squares traversed, episodes of grooming, and numbers of fecal boluses deposited during two minutes was recorded for the 16 sessions for each rat. After each rat was tested the floor was cleaned and wiped with a weak solution of vinegar. After the experiment the rats were returned to their home cages where they were maintained on food and water *ad libitum*. The primary analysis was a four way analysis of variance with all levels repeated (rotation speed, pattern, sham-field-no field, and time of testing).

The results of the four way analysis of variance indicated a statistically significant difference in ambulation only when the fields were either present ($n = 8$ days) or not present ($n = 8$ days) before the open field testing [$F(1,3) = 16.46, p = .02$; eta-squared = 85%]. This difference was due to the increased ambulation (mean and standard deviation in parentheses) following the field stimulation (49.4, 20) relative to the periods following no field stimulation (31.1, 15.9 squares). There was also a statistically significant interaction between the shape of the pulse and the time (day, night) of testing [$F(1,3) = 19.03, p = .02$].

Post hoc analysis indicated that the source of this interaction was due to the greater numbers of squares traversed during the night after exposure to the burst-firing pattern ($M = 63.1$) compared to the frequency-modulated pattern ($M = 28.0$) and no field conditions ($M = 30.2$) but greater numbers of squares traversed during the day following exposures to the frequency-modulated field ($M = 51.8$) compared to the burst-firing pattern ($M = 32.7$) or sham-fields ($M = 25.0$). No other effects were statistically significant. There were no statistically significant differences as a function of the four treatments or their interactions for measurements of defecation or episodes of grooming.

These results indicate that the more complex spatiotemporal configurations of weak magnetic fields can produce robust within subject effects of sufficient magnitude to require few subjects. The results also showed that different patterns of magnetic fields presented successively through the different spatial planes may be differentially effective during the day or night. It may be of interest that increased ambulatory activity, but with a much less effect size, has been reported after removal from 0.5 Hz rotating magnetic fields of strength 1,000 times the magnitude employed in the present study (Persinger et al., 1972).

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